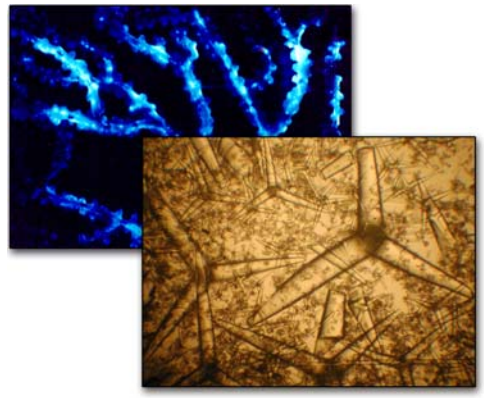
Islands in the Stream 2002: Exploring Underwater Oases

NOAA: Office of Ocean Exploration

Mission Three: SUMMARY

Discovery of New Resources with Pharmaceutical Potential (Pharmaceutical Discovery)

Exploration of Vision and Bioluminescence in Deep-sea Benthos (Vision and Bioluminescence)



Microscopic view of a *Pachastrellidae* sponge (front) and an example of benthic bioluminescence (back).

August 16 - August 31, 2002

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ABSTRACT

Harbor Branch Oceanographic Institution (HBOI) scientists continued their cutting-edge exploration searching for untapped sources of new drugs, examining the visual physiology of deep-sea benthos and characterizing the habitat in the South Atlantic Bight aboard the *R/V Seaward Johnson* from August 16-31, 2002. Over a half-dozen new species of sponges were recorded, which may provide scientists with information leading to the development of compounds used to study, treat, or diagnose human diseases. In addition, wondrous examples of bioluminescence and emission spectra were recorded, providing scientists with more data to help them understand how benthic organisms visualize their environment. New and creative ways to outreach and educate the public also played key roles throughout the mission. The successful cruise included 23 submersible dives that resulted in 29 hours of digital video of *Lophelia* reef habitat and fauna in areas not previously surveyed for biology. In all, more than 56 hours of fathometer transects and 24 hours of Tucker trawls and SeaCat CTD's were completed. Further laboratory tests on samples collected will be conducted to determine if any samples yield compounds that can be further analyzed for pharmaceutical use.

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KEY FINDINGS AND OUTCOMES

Findings

More than 29 hours of digital video documented the deep reef habitats and biota studied from Stetson Bank, SC to Cape Canaveral, FL. Several deep-water *Lophelia* lithoherm pinnacles were explored and characterized biologically, during which bioluminescence and vision tests were conducted, including deployment of the Eye-in-the-Sea camera.

Pharmaceutical Discovery:

Discovery: A 500-ft-tall coral pinnacle was discovered at the Stetson Reef site on the eastern edge of the Blake Plateau which consisted of live bushes of *Lophelia* coral and coral debris on its flanks. The crest consisted of a flat plateau at 2050 ft covered with live coral, sponges, gorgonians, and black coral bushes.

Fathometer Transects: Hundreds of 50-500-ft-tall *Lophelia* deep-water coral pinnacles of incredible habitat, coral, sponges, and gorgonians, were revealed during fathometer transects along a 120-mile stretch off the coast of Florida at depths of 2400 ft from Jacksonville to south of Cape Canaveral.

Abundance and Diversity: The abundance and diversity of sponges and octocorals was greater than previously reported in the literature.

New Species: Several new species or new records of occurrence of sponges and octocorals were documented.

Novel Compounds: Chemical profiles of sponge and octocoral extracts indicated that novel compounds were present in many of the samples.

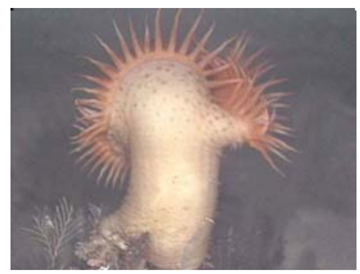
Bioactivity: Antimicrobial activity was exhibited by several species, as determined by shipboard disk diffusion assays. No sample showed activity in all bioassays, i.e., selective bioactivity was observed.

Vision and Bioluminescence:

Benthic Traps: The benthic traps worked as designed, capturing two live healthy crabs, insulating them against thermal changes on return to the surface, and protecting their extremely sensitive photoreceptors from damaging levels of light.

Electrophysiology: Electrophysiological recordings of a live galatheid crab and a live portunid crab indicate that the eyes are extremely sensitive to light, with maximum sensitivity in the blue end of the spectrum. Given the depth at which they were collected, they may be adapted to see very low levels of downwelling light.





From top to bottom: *Phakellia* fan sponge, *Keratoisis flexibilis* bamboo coral, fly trap anemone, Lithistid sponge, juvenile *Beroe* ctenophore under a fluorescent lamp.

Eye Glow: From the submersible, scientists observed two crab species with apparent intense eye glow. Histological examinations will determine if these crabs possess the unusual parabolic superposition eye.

Bioluminescence: Spectacular examples of bioluminescence were documented and emission spectra recorded in a variety of benthic organisms. Observations from the submersible with the lights off indicated a variety of luminescent sources with emission properties different from the identified sources.

Eye-in-the-Sea Camera: Technical difficulties hindered Eye-in-the-Sea recordings. Limited recordings showed some fishes around the trap that did not appear to react to the red light produced by the Eye-in-the-Sea.

Spectral Reflectance: Preliminary results of ultraviolet and visible wavelength tests of various substrates showed a high UV reflectance and suggested an adaptive reason for differences in red saturation between pelagic and benthic species.

Fluorescence: A number of fluorescent organisms were collected and will be used in molecular phylogenetic studies of the evolution of bioluminescence color as well as cloned for potential applications in genetic engineering research.

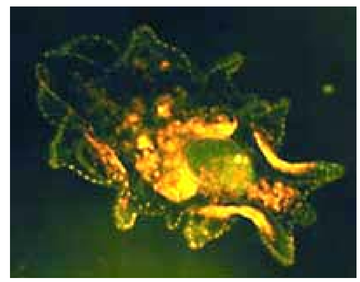
Outcomes

Ocean Explorer Web Site: Near real-time postings of logs, pictures, and video clips describing daily at-sea activities and discoveries, were submitted daily by mission scientists and educators. Thousands of users from all over the world followed the expedition daily.

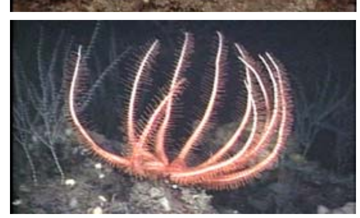
HBOI At-Sea Web Site: Complementary to the Ocean Explorer (OE) web site, this site offered additional stories, photos, and video clips to a well-established viewer base.

Education Benefits: During the mission there was a Teacher-at-Sea, lesson plans were developed and posted on the OE web site, sea-to-shore conference calls were conducted with teachers as part of a Professional Development Institute, field data was collected for a graduate student and guided student tours were given during an "open house". Post mission, presentations were made at the National Marine Educators Association and there were collaborations and exhibits organized with the SC Aquarium. A Professional Development Institute is planned at the HBOI campus to familizarize Florida educators with the OE program and curriculum. There will also be presentations on educational components at the National Science Teachers Association, the American Geophysical Union, and the Marine Technology Society.

Media Coverage: Several local newspaper stories were published in Florida. Digital video highlight tapes with annotation were distributed to regional and national markets.





From top to bottom: scorpionfish, fluorescent unidentified larva, red crab, unidentified skate or ray, sea star, red sea star (*Brisingia* sp.)

RATIONALE AND OBJECTIVES

Unlike the previous two missions of the Islands in the Stream 2002 Expedition, this mission consisted of two different projects, each with its own objectives. Many of the objectives of each project were met concurrently during submersible dives. This mission provided the opportunity for HBOI scientists to work together as an interdisciplinary team for the first time in the history of the organization.

Pharmaceutical Discovery

The first project, Pharmaceutical Discovery, focused on natural products and their potential for pharmaceutical use. Naturally-derived drugs have traditionally come from our planet's rich terrestrial sources. It has been predicted, however, that the marine environment may contain as much as 80% of the world's plant and animal species. This huge potential for new medicines from our oceans has already proven to be worthwhile as 12 marine natural products are currently in advanced preclinical or clinical evaluation.

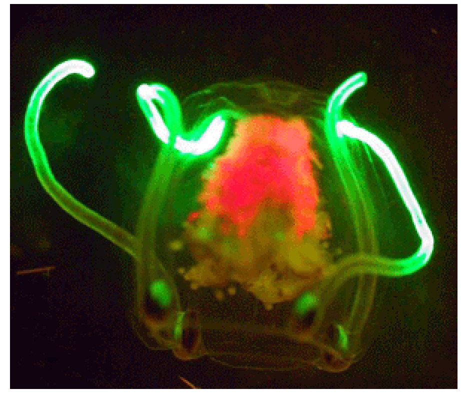
This project sought to explore currently untapped sources of new drugs that may be applied to the development of compounds used to study, diagnose, or treat human diseases, including cancer, infectious diseases, diseases of the immune system, cardiovascular disease, and central nervous system disorders. Related to this primary objective is the development of alternative methods for production of bioactive compounds other than harvesting organisms from nature. Specific project objectives were to:

- collect benthic invertebrates for biomedical research;
- document the biodiversity of benthic communities;
- isolate and culture microorganisms;
- prepare extracts of micro- and macroorganisms for bioactivity screening;
- preserve sub-samples for a molecular genetics program; and
- analyze extracts for chemical activity.

A shaving cream sponge (left) and Hexactinellid sponge (right), as seen from the *Johnson-Sea-Link II* submersible.

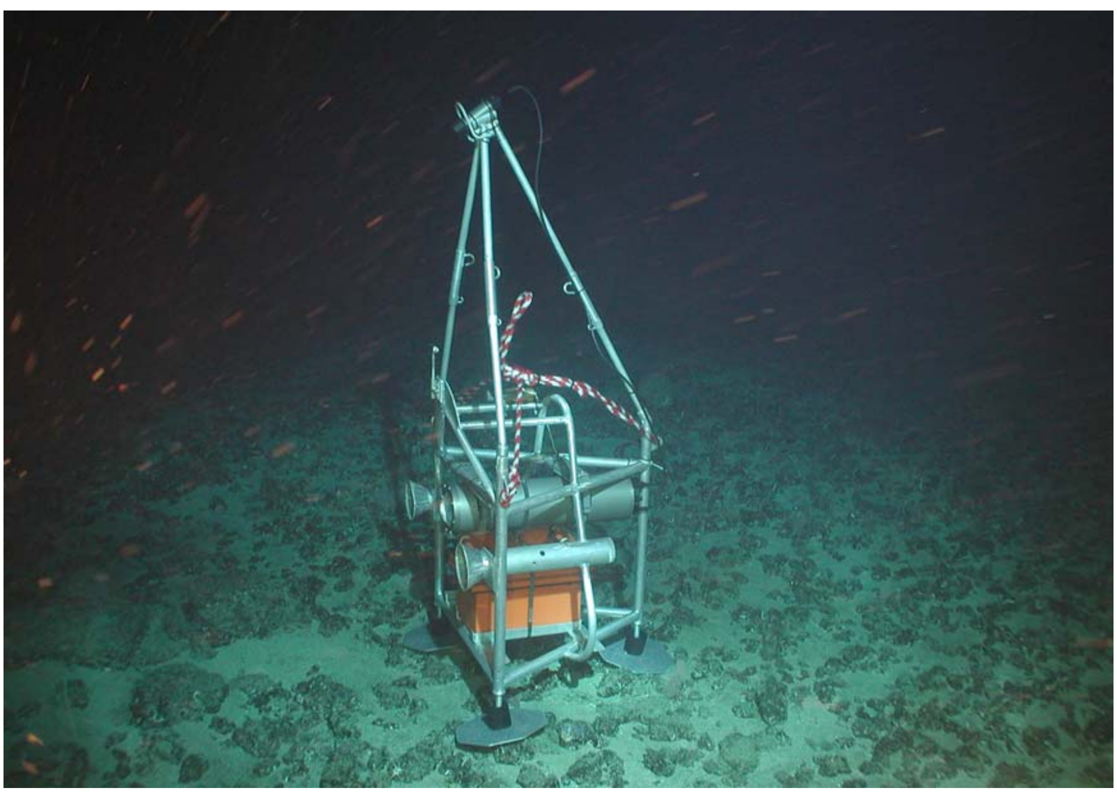
Vision and Bioluminescence

The second project, Vision and Bioluminescence, explored the visual physiology of deep-sea benthic organisms as well as their visual environment, focusing particularly on bioluminescence. Scientists had observed that the eyes of highly mobile (pelagic) fish species tend to get smaller as ocean depths increase, an apparent adaptation to low light levels with increasing depth. Scientists have also discovered that the eyes of bottom- (benthic) dwelling species, in fact, increase in size with depth. The science party aboard this mission sought to understand why species living at the bottom of the ocean have large eyes and determine what these large-eyed species see when virtually no sunlight is capable of reaching these depths. They also investigated the presence of bioluminescence on the seafloor to perhaps unveil what these benthic creatures see. Specific project objectives were to:



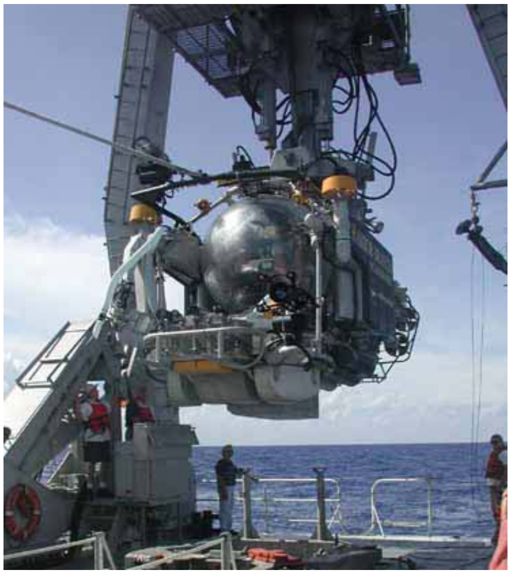
Fluorescence from a bioluminescent jellyfish.

- collect specimens with intact visual systems;
- observe the visual environment unobtrusively using the Eye-in-the-Sea deployable camera system;
- explore for unknown sources of bioluminescence and fluorescence; and
- measure the spectral distribution of downwelling irradiance.



The Eye-in-the-Sea mounted camera on the seafloor.

OPERATIONS AND SCHEDULE



Launching the *Johnson-Sea-Link II* submersible from the *R/V Seward Johnson*.

This mission was staged from the Port of Charleston Passenger Terminal, Charleston, SC, on August 16 aboard the *R/V Seward Johnson* (*SJ*), the support vessel for the submersible *Johnson-Sea-Link II* (*JSLII*). Following a full day of education and outreach activities including a VIP breakfast, media event, and student tours on August 17, the *SJ* got underway early in the morning on August 18. Arriving on site at the Stetson *Lophelia* Banks on August 19, the scientists and crew began a busy schedule of submersible dives and sampling activities through August 22. From August 23-24, submersible and science activities occurred in the Charleston Lumps North and South regions. From August 25-27 operations continued at the Savannah lithoherm region. On August 28, several sites previously visited by the Navy's NR-1 submersible on the Blake Plateau were surveyed by fathometer. Continuing gradual movement south, the mission explored the Jacksonville and Cape Canaveral areas using dives and science operations from August 29-30. The mission and expedition ended at 16:30 (EDT) on August 31 when the *SJ* arrived home at HBOI in Ft. Pierce, Florida. In all, a total of 14 sea days supporting 12 days of sub and shipboard science activities had been completed.

		Sub	Bathymetry	Sampling			CTD
Date	Location	JSL-II Dive	Fathometer	Tucker Trawl	Plankton Net	Blue Water Dives	Conductivity, Temperature, Depth
16-Aug	Charleston, SC	Mobilize					
17-Aug	Charleston, SC	Education and Outreach Day					
18-Aug	Charleston, SC	Transit					
19-Aug	Stetson Lophelia Bank, SC	■	■	■			■
20-Aug	Stetson Lophelia Bank, SC	■	■	■	■		■
21-Aug	Stetson Lophelia Bank, SC	■	■	■	■		■
22-Aug	Stetson Lophelia Bank, SC	■	■	■	■		■
23-Aug	Charleston Lumps South, SC	■	■	■	■		■
	Charleston Lumps Nouth, SC	■	■	■	■		■
24-Aug	Charleston Lumps North, SC	■	■	■	■		■
25-Aug	Savannah Lithoherm, GA	■	■	■	■		■
26-Aug	Savannah Lithoherm, GA	■	■	■	■	■	■
27-Aug	Savannah Lithoherm, GA	■	■	■	■		■
28-Aug		Weather	■		■		
29-Aug		■	■	■	■		■
30-Aug		■	■				■
31-Aug		Transit					

Submersible and shipboard activities conducted at each reef site.

SITE AND TARGET SELECTION

The general area of study included various little-known deep-water coral reefs, lithoherms, and live bottom rock reefs within the South Atlantic Bight. The specific areas included the Florida-Hatteras and western and eastern Blake Plateau off Florida, Georgia, and South Carolina. Six general regions were selected for exploration following a thorough analysis of publications and unpublished data from biologists and geologists who had previously studied selected regions in the area.

Typical Submersible Dive

- launch from ship
- once on bottom, transit to target location
- deploy Eye-in-the-Sea (1st dive)
- deploy or recover benthic traps
- video document reef habitat, fishes and invertebrates
- collect invertebrates, fish, rock, sediment, and coral
- recover Eye-in-the-Sea (2nd dive)
- return to ship

Except for the Charleston Lumps regions, little or no information was available for most of the pre-selected dive locations. Therefore, fathometer transects were made (often for most of the night) when approaching each new area. Features of particular interest were high-relief ridges and pinnacles—generally the location of diverse hard-bottom invertebrate communities. Collection site coordinates were then determined with GPS navigation.

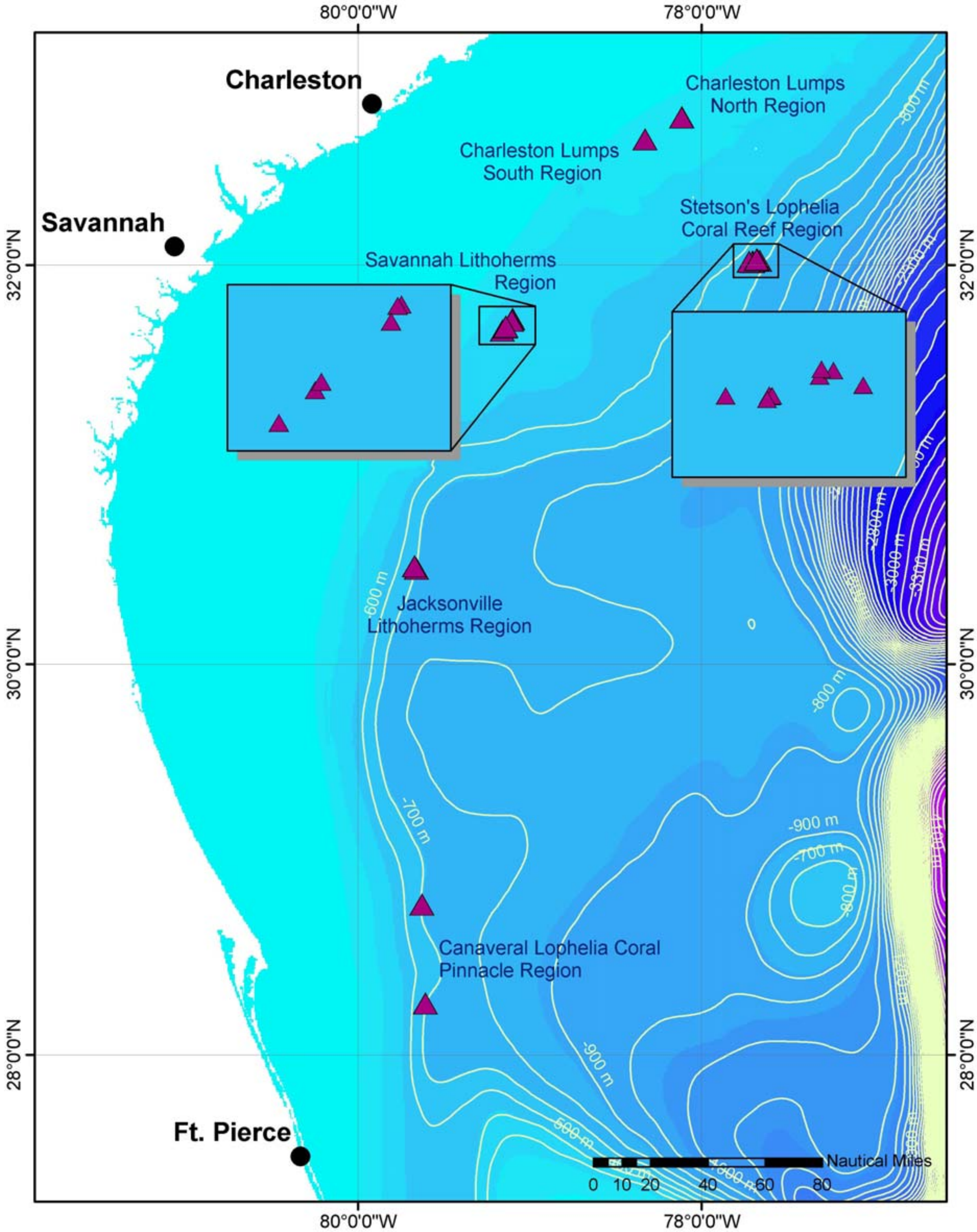
Dive Regions

As the JSLII rises to the surface near the ship, a swimmer must jump in to the water to manually attach a cord to the submersible. Here this task is performed by Jim Sullivan, member of the submersible crew.

1) Stetson's *Lophelia* Coral Reef: ~120 nm southeast of Charleston, SC; 2500-2000 ft maximum depth; Two *Lophelia* coral pinnacle sites: Pinnacle 3 and 500-ft-tall "Reed's Peak"
2) Charleston Lumps North: ~85 nm east of Charleston, SC; 674 ft maximum depth; phosphoritic ridges and boulders
3) Charleston Lumps South: ~90 nm east of Charleston, SC; 689 ft maximum depth; phosphoritic ridges and boulders
4) Savannah Lithoherms: ~90 nm east of Savannah, GA; 1782 ft maximum depth; lithoherm mounds of phosphoritic pavement and *Lophelia* coral and rubble
5) Jacksonville Lithoherms: ~90 nm east of Jacksonville, FL; 1950 ft maximum depth; 500-ft-tall lithoherm with *Lophelia* coral and rubble
6) Canaveral *Lophelia* Coral Pinnacle: ~50 nm east of Cape Canaveral, FL; 2486 ft maximum depth; 50-150-ft-tall *Lophelia* coral pinnacles

Typical Day

0000-0100	Tucker trawls with CTD to collect samples for vision and bioluminescence study, or transit to new operating area
0100-0200	Solid State Bathyphotometer measurements and small plankton net tows
0200-0600	Set and drift or fathometer surveys for profiling dive area topography
0600-0700	Fathometer surveys for profiling dive area topography
0700-0800	ADCP and set and drift for profiling dive area currents
0800-1200	Sub Dive #1
1200-1600	Transit to new dive target and fathometer surveys for topography
1600-2000	Sub Dive #2
2100-0000	Tucker trawls with CTD to collect samples for vision and bioluminescence study, or transit to new operating area



Leg 3 dive sites and regions.

SAMPLING

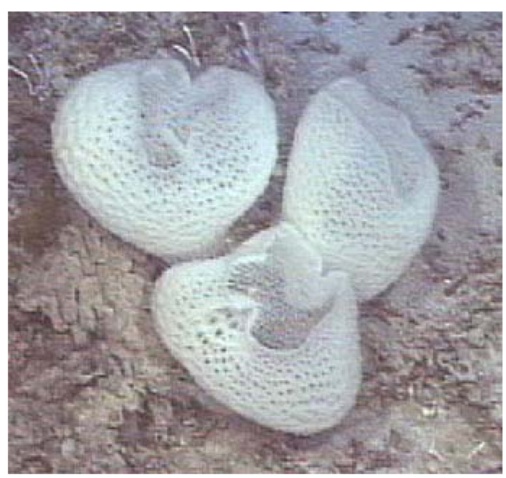
Two submersible dives (~3 ½ hours each) with the *JSLII* manned submersible were conducted each day: the Pharmaceutical Discovery group had one dive and the Vision and Bioluminescence group had one dive, however each group collected samples for the other which resulted in significantly more samples for evaluation by each group. The *JSLII* was equipped with 1) a manipulator arm that included a clam-shell grab, jaws, and suction hose; 2) a benthic platform that included a 12-bin rotating basket, color video camera, and 35-mm camera; and 3) a data recorder that logged time, temperature, conductivity, salinity, oxygen, and depth every second.

Pharmaceutical Discovery

Once samples for the Pharmaceutical Discovery Group (primarily sponges and octocorals) were brought on deck after a dive, they were photographed and subsampled for a variety of procedures, including:

- **Taxonomic Identification:** Preliminary field observations made at sea.
- **Microbial Isolation:** Samples to be used for microbial isolation were immediately subsampled after collection and prepared as an inoculum for a series of isolation plates that would then be incubated for 2 - 4 weeks.
- **DNA/RNA Preservation:** For each sample, four subsamples were prepared and stored at -80°C for future DNA extraction.
- **Chemical Extraction:** Ethanol extracts of the collected organisms were prepared at sea and then stored at -25°C until future use.
- **Chemical Evaluation:** To provide a preliminary indication of chemical diversity, macroorganisms were analyzed at sea by high performance liquid chromatography.
- **Antimicrobial Bioassays**: To obtain a preliminary shipboard assessment of potential bioactivity of the samples, antimicrobial disk diffusion assays were conducted.
- **Invertebrate Cell Culture:** Selected deep-water sponge samples were dissociated at sea into cell suspensions and separated by cell type using density gradient centrifugation. Cell fractions were then used to initiate primary cultures at sea and cryopreserved for subsequent research at HBOI.

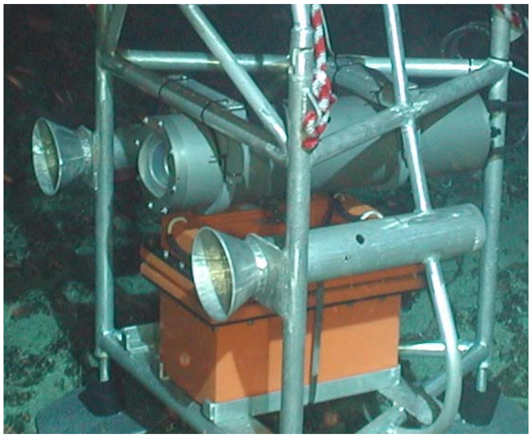
Tara Peterson Pitts (HBOI) collecting samples for her biomedical research.



Three white Hexactinellid cup sponges.

Vision and Bioluminescence

Sampling by the Vision and Bioluminescence Group required specialized equipment in addition to the traditional sampling from the *JSLII*.



Close-up of the Eye-in-the-Sea camera.

The **Eye-in-the-Sea** camera is a specially-designed camera that was left on the sea floor by the submersible for one or two days at a time to record the surrounding bioluminescence in the absence of bright lights and loud noise of the submersible. Because the Eye-in-the-Sea's hard disk failed during the first deployment, it was not possible to collect many images of bioluminescent sources. The launch and recovery of the Eye-in-the-Sea from the JSLII and the collection of some images worked well however, indicating that this new system can be fully functional with the investment of a bit more development time and money.

Light-tight, insulated **benthic traps** were also deployed from the *JSLII* submersible to collect organisms and bring them to the surface without blinding them or damaging their eyes with the relatively bright light at the surface. The open, baited traps were deployed on one dive, closed after 2-4 hours via a magnesium link system, and retrieved on another dive. Crabs collected with these traps were put into a light-tight holding room prior to electrophysiology experiments and eye removal for histological examination.

One of the benthic traps on the sea floor.

Fish specimens collected by the Tucker trawl.

After sunset, a **Tucker trawl** was deployed for approximately three hours. It was equipped with a light-tight cod-end that could be closed at depth by a net timer, providing live animals in excellent condition.

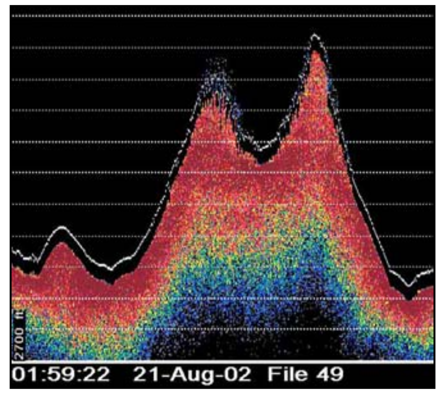
Before the **plankton net** was lowered into the water, a Solid State Bathyphotometer was deployed off the starboard side of the ship to determine the depth of maximum stimulated bioluminescence. The plankton net was then lowered to this depth for 15-30 minutes. Potentially-bioluminescent dinoflagellate collections were then isolated and tested for bioluminescence.

SITE DESCRIPTIONS

Multiple dives were conducted in each of the six dive regions. The following are descriptions of individual dives within these regions.

Stetson's *Lophelia* Coral Reef: "Reed's Peak", 8/20/02

At 500 ft, this reef represents one of the highest deep-water *Lophelia* coral pinnacles known. The lower slope, from 2500-2300 ft, had a gentle incline of 10-30 degrees with a series of terraces and ridges that had 100% cover of live and dead coral rubble, and a great diversity of associated fauna. The upper slope, from 2200 ft to the top at 2050 ft, was steeper, 45-90 degrees, with more exposed rock, and an even greater diversity and density of corals, sponges, and gorgonians. The top of the peak was flat, and no large fish were observed anywhere. Although there were no areas of extensive massive coral growth, there was an abundance of small, 6-12-inch live *Lophelia* corals.



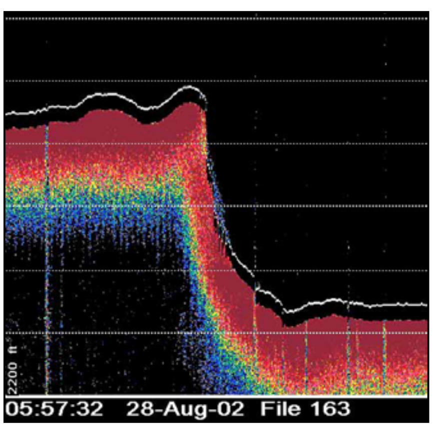
A fathometer profile of a section through "Reed's Peak".

Charleston Lumps North

Dive descriptions are in development for this region.

Charleston Lumps South: 08/23/02

At 690 ft, the base of this site, the area consists mainly of barren sand and an occasional sea urchin. From 660-630 ft, the area was relatively flat with 50% cover of rock cobble ½ - 1 ft in diameter and few animals. As the sea floor reached up to depths of 630-615 ft, there was increasing habitat with a series of 10-ft-high linear ridges in the NW-SE direction made of 1-2 ft phosphoritic cobble, rock slabs and boulders 3-6 ft in diameter. This area had a higher diversity of fish and invertebrates, but a relatively low diversity of macro-benthic species.



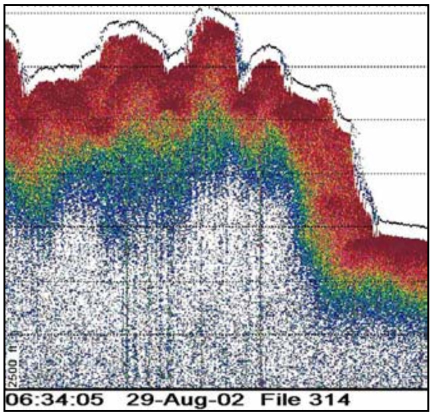
A fathometer profile of a 360-ft-tall vertical rock scarp in the Savannah Lithoherm region. No dives were actually made on this scarp.

Savannah Lithoherms: Site 1, 08/25/02

The lithoherm pinnacle visited on this dive rose up to a depth of 1600 ft from a base of 1800 ft. Towards the top, it sloped gently at 10 degrees and had 90% cover of sand and coral rubble, and occasional 6-inch ledges. At 1636 ft, there was a sharp ridge in the NW-SE direction, perpendicular to the current. The south slope consisted of a series of terraces and 10-ft, 45-degree escarpments. In general, there was dense (~10% cover) sponge and gorgonian growth, especially on the ridges, but relatively few species. *Lophelia pertusa* was common, but not abundant. The average size of its colonies was 6-12 inches. Few fish were observed.

Savannah Lithoherms: Site 2, Pinnacle 1, 08/27/02

This lithoherm pinnacle rose 135 ft from a base of 1760 ft. It had a 10-20 degree slope with sand, coral rubble, and phosphoritic pavement. There were also low (6-inch) ledges, and terraces and ridges. Towards the top the pinnacle slope was 45 degrees. Dense sponge and gorgonian growth was especially abundant on the ridges and top. *Lophelia pertusa* was common and abundant on the upper slopes, with an average colony size of 6-15 inches. Few fishes were observed.



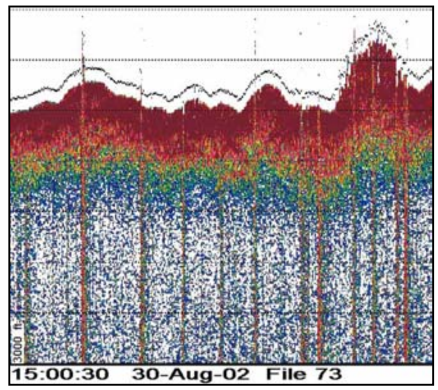
A fathometer profile of the Jacksonville lithoherm.

Jacksonville Lithoherms: 08/29/02

Previous geological studies in this area by Charlie Paull (Monterey Bay Aquarium Research Institute)[1] showed numerous high pinnacles and rugged terrain. Our fathometer transects south of his stations showed numerous peaks on a single 500-ft-tall pinnacle. The submersible dive was on a 338-ft-tall peak near the south end of the lithoherm pinnacle. Dive descriptions are in development for this region.

Cape Canaveral *Lophelia* Coral Pinnacles: Site 2, 8/30/02

This dive revealed a classic *Lophelia* deep-water coral reef pinnacle. With a 150-ft relief, the pinnacle base began at 2500 ft and rose to a series of peaks at 2340-2350 ft. The southern base and slope consisted of a series of 10-ft-high sand ridges that were covered with "thickets" aligned in the NW-SE direction. These "thickets" consisted of mostly dead, standing, intact *Lophelia*; only 5-10% was live coral. The slope at the base of the pinnacle was 10-20 degrees, but the slope increased to 45 degrees and then 70-80 degrees near the peak. The upper slopes had dense "thickets" of 3-5-ft-tall *Lophelia* and *Enallopsammia profunda* (=*Dendrophyllia profunda*) coral consisting of 1-3 ft of live coral on top of the intact dead bases; a total of 10-20% live cover. Although the reef was dense, the diversity of macrofauna throughout was low, consisting mainly of sponges and gorgonians. There were few fishes, mostly eels, scorpeanids and rattails.

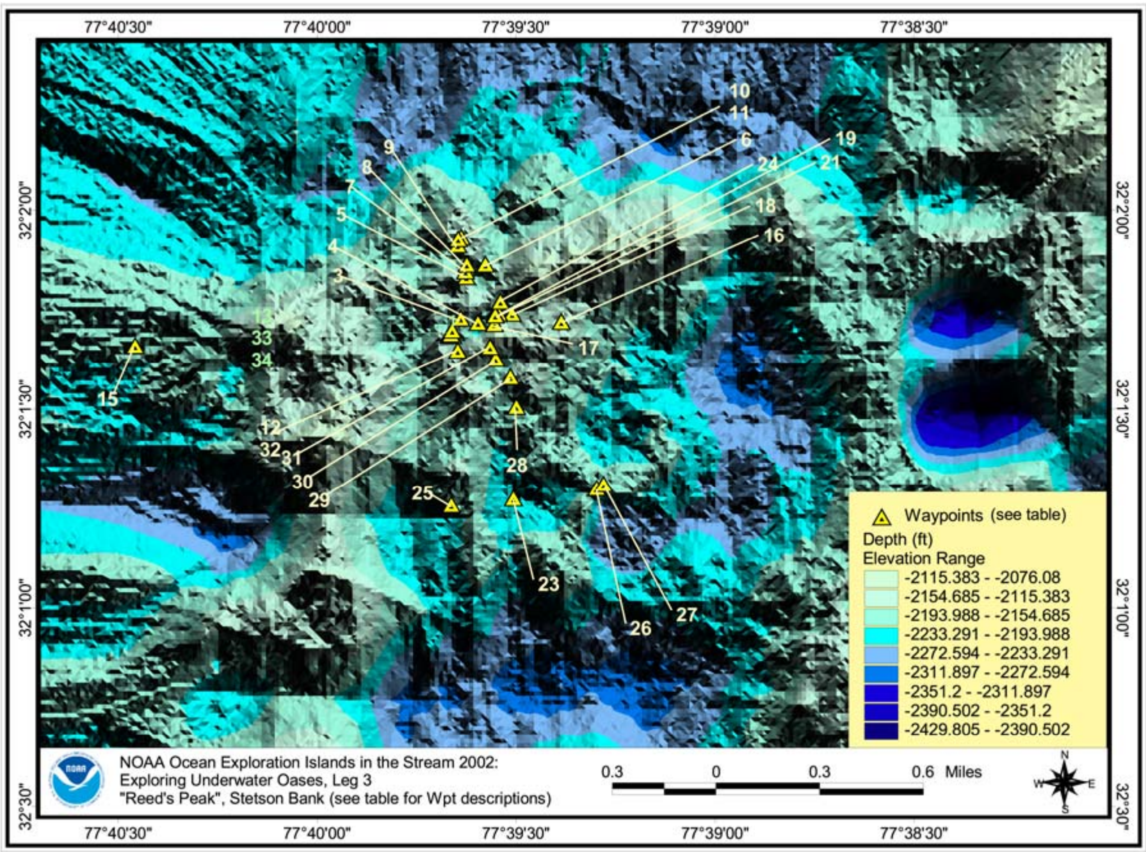


Two submersible dives were conducted on two of these 150-ft tall pinnacles in the Cape Canaveral region that proved to be *Lophelia* coral reefs.

[1] Paull, C.K., A. C. Neumann, B. am Ende, W. Ussler III, and N. Rodriguez. 2000. Lithoherms on the Florida-Hatteras Slope. Marine Geology 166: 83-101.

MAPPING THE DEEP-WATER REEF SITES

Fathometer transects were conducted at each dive site, resulting in 130 images of bathymetric profiles (24 mb, bmp and jpg files). In addition, a 20 mi^2 region at the Stetson's Reef site was surveyed by running 70 fathometer transect lines at intervals of 250 m (recording depth, latitude and longitude every ~3 seconds), resulting in a 3-D bathymetric GIS Arcview map (see below).



Wpt	Comment
1	traps
2	launch
3	on bottom 2059 ft
4	collection sample #1
5	north edge
6	collection sample#5
7	collection sample #6
8	collection sample #7
9	collection sample #8
10	collection sample #9
11	leaving the bottom
12	target site 2200 ft

Wpt	Comment
13	top of pinnacle 2060 ft
14	traps 2060 ft
15	launch
16	on the bottom
17	collection sample #1
18	collection sample #2
19	collection sample #7
20	another sample #7
21	collection sample#8
22	leaving bottom
23	base
24	big peak

Wpt	Comment
25	launch
26	bottom report
27	sample #4
28	30* slope
29	sample #11
30	45* slope
31	vertical surface 2220'
32	sample #12 2200'
33	on top 2065'
34	leaving bottom 2060'

This 500-ft-tall pinnacle, "Reed's Peak", within Stetson's *Lophelia* Coral Reef Site, was mapped using fathometer transects during this mission. It is overlain with submersible transects and sample collection points.

VISUAL ECOLOGY & BIOLUMINESCENCE FINDINGS

The two crustaceans (galatheid crab and portunid crab) that were retrieved from the benthic traps were very healthy, allowing for the first ever electrophysiological recordings from deep-sea benthic organisms with intact eyes. The very slow flicker fusion frequencies, which are an indication of temporal resolution, suggested that these eyes were designed for long integration times to maximize their sensitivity to light. Spectral sensitivity also peaked in the blue region of the spectrum, suggesting that the eyes were designed for maximum sensitivity to the available downwelling light, as well as bioluminescence.

Galatheid crab similar to one of the specimens captured with the benthic traps

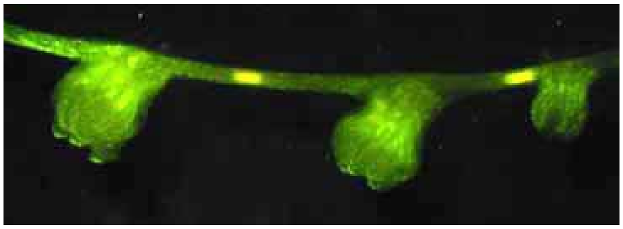
Dr. Peter Herring examining an organism for his bioluminescence research.

From the submersible, galatheid crabs and portunid crabs were observed to have intense eye glow. This is quite novel, as crabs in general have apposition eyes, and therefore eye glow is absent. One explanation is that these eyes may be an unusual type of photoreceptor called a parabolic superposition eye[2]. Histological examinations of the eyes of the crabs caught in the benthic traps should determine if these crabs possess this type of eye.

The apparent low abundance of luminescent sources in these benthic environments as compared to those found in mesopelagic depths is intriguing. However, sources of bioluminescence that were observed from the submersible but not identified may indicate that the well-developed eyes of benthic organisms are, in fact, adapted for seeing bioluminescence. Since sunlight was still present at the relatively shallow depths of the operating areas on this cruise, it is possible that future investigations at deeper depths will reveal a greater abundance of bioluminescence.

It was very clear from this initial investigation that this is a very complex visual environment and understanding the forces that have shaped such unusual visual adaptations may enhance our understanding of the ecology of these rich bottom habitats. Based on the reflectance measurements collected during this preliminary study, a model is being developed that may help account for the sometimes surprising coloration of deep bottom dwellers.

Another exciting discovery involved the collection of a number of fluorescent organisms. These specimens were preserved and will be used to clone Green Fluorescent Protein-like proteins that may have applications in genetic engineering research and will be used in molecular phylogenetic studies of the evolution of bioluminescence color.



Two different views of bamboo coral, under white light (left) and under a UV lamp (right).

[2] D.-E. Nilsson. A new type of imaging optics. 1988. Nature 332: 76-78

APPLICATION TO MANAGEMENT

A proposal for the first deep-water coral Marine Protected Area in the world was submitted by John Reed (HBOI) in 1982 to the South Atlantic Fishery Management Council and was enacted in 1984 as a 92 mi^2 *Oculina* Habitat of Particular Concern (OHAPC) off Florida's east coast. In 2000, the OHAPC was expanded to ~300 mi^2, encompassing the shelf-edge deep-water series of reefs from Fort Pierce to Cape Canaveral, Florida. Unfortunately the designation for the northern half of the reserve may have come too late, as submersible dives made in 2001 during NOAA's Ocean Exploration Islands in the Stream Mission found mostly dead coral rubble at many sites in the recently expanded region[3]. This area had been fished heavily for at least 20 years and shrimp trawlers had been caught dragging their steel doors and nets through this reserve as recently as last year. Evidence shows that such activities have decimated once thriving reefs.

A sample of *Lophelia* deep-water coral.

The deep-water *Lophelia* coral reefs discovered during this mission are similar in structure to the *Oculina* reefs. These were some of the first dives ever made to document the habitat and benthic biodiversity on these relatively unknown *Lophelia* coral reefs, especially on the eastern Blake Plateau and the Straits of Florida. The resource potential is unknown in terms of potential fisheries and novel compounds yet to be discovered that may produce pharmaceutical drugs. Although there are not yet plans to designate these as MPAs, they are an incredibly diverse and irreplaceable resource. Many of these structures may be tens of thousands of years old, as suggested by evidence from previous carbon dating of *Lophelia* coral debris. The coral itself is slow growing, only 10-20 mm/year, and is very fragile. Any activities involving bottom dredging, trawling, pipeline laying, or oil/gas production could negatively impact these unique reef habitats.

Deep-water black coral.

[3] http://oceanexplorer.noaa.gov/explorations/islands01/islands01.html

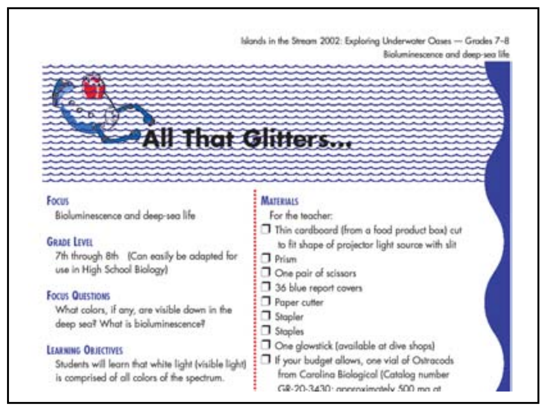
EDUCATION AND OUTREACH

New discoveries at sea made by an interdisciplinary team of world-class scientists using state-of-the-art sampling technologies coupled with the near-real time capabilities of the Internet offered rich opportunities to capture the interest of the American public during this third leg of the expedition. Through both formal and informal education and outreach efforts that were specifically tied to this voyage of discovery, NOAA embraced the fourth key recommendation of the Presidential Panel Report (Discovering Earth's Final Frontier: A U.S. Strategy for Ocean Exploration) - that of "reaching out in new ways to stakeholders to improve the literacy of learners with respect to ocean issues. Education and outreach efforts as part of this mission are described below.

Education

Lesson Plan Development

Seven educators and four scientists working with NOAA during June and July 2002 developed a total of 13 lesson plans for students in Grades 5 – 12 that are specifically tied to the Islands in the Stream 2002: Exploring Underwater Oases expedition. The lesson plans focus on the exploration efforts taking place during the expedition, and feature such topics as spawning habitats and behaviors of reef fishes, topographic features of the region, biological communities found on hard bottom areas, vision and bioluminescence in the deep sea, and shipboard navigation.



Islands in the Stream 2002: Exploring Underwater Oases — Grades 7-8
Bioluminescence and deep-sea life

All That Glitters...

FOCUS
Bioluminescence and deep-sea life

GRADE LEVEL
7th through 8th (Can easily be adapted for use in High School Biology)

FOCUS QUESTIONS
What colors, if any, are visible down in the deep sea? What is bioluminescence?

LEARNING OBJECTIVES
Students will learn that white light (visible light) is comprised of all colors of the spectrum.

MATERIALS
For the teacher:
- ❒ Thin cardboard (from a food product box) cut to fit shape of projector light source with slit
- ❒ Prism
- ❒ One pair of scissors
- ❒ 36 blue report covers
- ❒ Paper cutter
- ❒ Stapler
- ❒ Staples
- ❒ One glowstick (available at dive shops)
- ❒ If your budget allows, one vial of Ostracods from Carolina Biological (Catalog number GR-20-3430; approximately 500 mg at

An example of one of the lesson plans.

In addition to being tied to the National Science Education Standards, the hands-on, inquiry-based activities include focus questions, background information for teachers, links to interesting Internet sites, and extensions. Web logs that document the latest discoveries and complement the lesson plans, complete with compelling images and video, were sent back each day from sea for posting on the Ocean Explorer web site. Teachers were encouraged to use the daily logs to supplement the lesson plans. Adaptations for teachers of deaf students are currently under development for these lessons. All of the lesson plans are available in pdf format, and may be viewed and printed with the free Adobe Acrobat reader from the Ocean Explorer web site. A description of each lesson can be found in Appendix 4.

Islands in the Stream 2002 Professional Development Institutes

A total of 62 teachers and other educators participated in three Islands in the Stream 2002 Professional Development Institutes (PDI) in North Carolina, South Carolina, and Georgia. The University of North Carolina, Wilmington and North Carolina Sea Grant (21 participants); the NOAA Coastal Services Center in Charleston, South Carolina (27 participants); and NOAA Gray's Reef National Marine Sanctuary in Savannah, Georgia (14 participants) were host sites for these programs. Each PDI was funded by the NOAA Office of Ocean Exploration and included a daylong exchange among scientists and educators about the exploration and research taking place during the Expedition. Teachers received copies of the lessons described above, which were conducted and/or demonstrated during the PDI. An overview of the Ocean Explorer website and other supporting resources were included in the program. Teachers also learned how their students could communicate with scientists at sea via the "Ask an Explorer" section of the website. A live audio chat was also held with teachers participating in each PDI and scientists and submersible pilots at sea through satellite phone communications to the PDI sites. Each teacher participating in the PDI received an evaluation packet that included evaluation instruments for the PDI, an evaluation for the teacher to use after his/her participation in the classroom component of the program, and pre- and post-student attitudinal survey instruments.

Outreach

The Smithsonian Associates Aquanaut Camp

The Office of Ocean Exploration teamed with The Smithsonian Institution to offer a week-long summer camp experience for 16 children in grades 5 through 8. Entitled "Aquanauts Exploring the Oceans," the camp was offered through The Smithsonian Associates Program from August 5–9, 2002. Instructors were identified and a curriculum that focused on the science of the Islands in the Stream 2002 Expedition was developed for use during the program. NOAA personnel were present to support camp activities and gave several presentations to the camp participants during the course of the week. Additionally, an hour-long audio chat was held with scientists and submersible pilots during Leg 2 of the Expedition as students located at The Smithsonian Institution's Ripley Center communicated with the *SJ* at sea. The program culminated in a Visitors' Day during which families and others learned about the exploration in the ocean environment through the experiences of the camp participants. The campers also created their own web page as part of the experience.

Paula Keener-Chavis, the national education coordinator for the Office of Ocean Exploration, shared her undersea experiences, then listened as the summer Aquanauts described the topographical global map they had constructed from plaster.

Ocean Exploration Port Day

Over 300 students and their teachers toured the NOAA Ship *Ronald H. Brown* and the HBOI research vessel *SJ* during a special Ocean Exploration Port Day held August 17, 2002, in Charleston, South Carolina. The teachers who toured the vessels had recently participated in the PDI designed to engage their students in lessons that are tied to the exploration and research taking place as part of the Expedition. Scientists and vessel crew spent the better part of the day talking with the visitors about spawning aggregations of fishes and other discoveries made during Legs 1 and 2 of the Expedition, as well as biomedical compounds from the sea, visual ecology of benthic animals, and bioluminescence to be explored during Leg 3. Teachers and students also got to see the *JSLII* submersible as well as several education and outreach exhibits set up by other organization/agency personnel at the South Carolina State Ports Authority Passenger Terminal. Participating groups included the South Carolina Department of Natural Resources, the University

A group of students learning about the *JSLII* as they tour the *SJ* during the special Ocean Exploration Port Day held August 17.

of North Carolina - Wilmington National Undersea Research Program, the Gray's Reef National Marine Sanctuary, the University of South Carolina's Hobcaw Barony National Estuarine Research Reserve System, and the South Carolina Aquarium. A private vessel tour for dignitaries was also held as part of the event.

Web Sites

oceanexplorer.noaa.gov

The Islands in the Stream: Exploring Underwater Oases 2002 section of the Ocean Explorer web site includes a Mission Plan, an Education section that includes the lesson plans in pdf format that can be viewed and printed with the free Adobe Acrobat reader from the web site, seven essays, and an Explorers section. Spawning Grounds, Reef Fishes, Midwater Ecology, Coral Reefs, Better Medicines, and Visual Ecology & Bioluminescence are topics of the essays, which were written by scientists participating in the Expedition.

One of the many pages that is a part of the oceanexplorer web site.

A total of 13 daily web logs, complete with compelling images and video, were submitted by the NOAA Web Coordinator at sea for posting on the web site throughout the Expedition. Web logs not only kept readers up-to-date with events occurring during the Expedition, but also included special editorials written by expedition participants and interviews with scientists, graduate students, and vessel crew. The Ask an Explorer section includes questions posted by students and the scientists' response to those questions. In addition to these efforts by NOAA, an HBOI Web Coordinator contributed daily logs and images to the HBOI site (www.at-sea.org). Hypertext links were established for both sites. Appendix 5 lists date, title, subject, and author of the web logs submitted to the OE website during Leg 3.

www.at-sea.org

Harbor Branch Oceanographic Institution dispatched a correspondent on this leg of the Ocean Exploration mission to provide daily, near-real time reporting for its web site entitled @sea (www.at-sea.org). The site chronicles the at-sea adventure, exploration and discovery primarily of Harbor Branch scientists aboard Harbor Branch research vessels.

The @sea web site by Harbor Branch.

This offering, entitled "Nature's Pharmacy and Eyes in the Sea" provides on-line reporting, educational preview essays and information about the researchers and the technology they use. It is intended to complement the postings appearing on NOAA's Ocean Exploration web site (oceanexplorer.noaa.gov). The NOAA web site is linked via hypertext to the Harbor Branch site and vice-versa, as are other links germane to the mission (www.biolum.org for example). Appendix 6 lists date, subject, and author of the web logs submitted to the @sea website during Leg 3.

In addition to reporting for the @sea site, the correspondent assisted the NOAA Web Coordinator with the processing of visual content for the Ocean Exploration web site, and documented aspects of the mission using broadcast-quality video production equipment (BetaSP). The resulting material will enhance HBOI's archive of mission documentation, and is available to NOAA for use.

Teacher-at-Sea

Arte Roman, Teacher-at-Sea.

Arte Roman, a marine science teacher from Olympia High School near Orlando, Florida, joined Dr. Edie Widder on board the *R/V Seward Johnson* on Leg 3. His responsibilities included assisting Dr. Widder as needed. In addition to submitting a daily log for the web site, NOAA staff initiated additional education activities for Mr. Roman while he was at sea, including the development of a 30-second video that was sent via email to Olympia High School for a school-wide broadcast, encouraging students at the school to submit questions to the Ask an Explorer section of the web site, and the development of a news release about Mr. Roman's participation in the Expedition to be posted on the HBOI @sea web site. In addition, a total of 20 drift bottles were deployed as part of a class experiment for a South Carolina high school teacher who participated in a PDI.

One of the drift bottles moments before it was thrown from the *SJ* out to sea for a high school experiment.

MEDIA COVERAGE

Post-cruise products, such as annotated digital video highlights and annotated digital still images, were developed and distributed to regional and national markets. Several articles appeared in local newspapers throughout Florida.


The Stuart News
August 18, 2002
Plumbing the depths
Explorers hope ocean holds next wave of cu
By Suzanne Wentley
Scientists return from deep-sea mission
By Rachel Harris
Press Journal
WWW.PRESSJOURNAL.COM
GOOD MORNING!
Sept. 1, 2002
BACK FROM SEA
Scientist John Reed, of the Bio Medical Research Division at Harbor Branch Oceanographic Institute, holds up samples of glass sponge (left) and deep-water coral brought up from a recent trip. Story, A10.

Title	Author	Organization	City	Page	Date
Explorers hope ocean holds next wave of cures	Suzanne Wentley	The Stuart News	Stuart, FL	A1, A10	8/18/02
Harbor Branch team to explore Atlantic	Suzanne Wentley	Vero Press Journal	Vero, FL	A10	8/18/02
Scientists receive NOAA funding for ocean exploration mission	HB staff	Harbor Branch Bulletin	Fort Pierce, FL	6, 7	Summer 2002
Harbor Branch mission ends	Rachel Harris	Vero Press Journal	Vero, FL	1, A10	9/1/02
Scientists return from deep-sea mission	Rachel Harris	Fort Pierce News Tribune	Fort Pierce, FL	B1, B2	9/1/02

THOUGHTS FOR THE FUTURE

Pharmaceutical Discovery:

This mission documented newly-discovered deep-water reefs within US waters. Although previous geological studies had surveyed some of these sites, virtually nothing was known about the biology and biodiversity of these diverse habitats. Funding for ship and submersible time from NOAA's Ocean Exploration program enabled this mission to make 23 submersible dives in areas never dived before. The science team was able to document the benthic macrofauna and habitats with approximately 29 hours of videotapes, 160 underwater and 508 shipboard digital still images, and 200 specimens of sponges, octocorals, scleractinian corals, crustaceans, echinoderms, and sediment samples. Initial taxonomic analyses indicated that several sponges and gorgonians may be species new to science, and many are certainly range extensions. Initial results of specimens tested for natural products indicate that many specimens show promising chemistry. A number of active specimens were identified and will be the subject of continued investigation in the HBOI laboratories. Subsamples made from each sample were also frozen and archived for the HBOI Department of Biomedical Marine Research Molecular Genome ARK that will provide material for investigation by future generations.

The samples collected are certain to contain novel compounds that will show promising biological activities. These compounds will start the oftentimes-arduous road toward new drug approval. Funding for these research missions is essential in allowing for the exploration, discovery, documentation, characterization, and preservation of new habitats which contain resources that have the potential for human application through the discovery of new therapeutic agents which can treat existing and newly emerging diseases.

Vision and Bioluminescence:

This mission demonstrated that it is possible to study life in the deep-sea without the destructive use of artificial lights. The new trapping methodology was successful at retrieving benthic crustaceans with intact visual systems. Some modifications are required to increase the catch, but clearly, this methodology can work successfully at depths below which downwelling light can reach, allowing scientists to gain an understanding of what the huge eyes of these very deep-living benthic crustaceans are adapted for seeing. The Eye-in-the-Sea camera deployment demonstrated proof-of-concept, indicating that this unobtrusive observation tool can be used to record animal behavior using light that is invisible to the animals and hopefully will provide greater insight into the functions of bizarre visual and bioluminescence adaptations in benthic organisms.

This mission took place in the South Atlantic Bight, where bottom depths reached 2100 ft, such that some downwelling irradiance from the surface was still visible. Therefore, it was not possible to explore the possibility that the enormous eyes of benthic organisms were adapted solely for seeing bioluminescence. In order to further explore this idea, both the traps and the Eye-in-the-Sea need to be deployed at depths below which downwelling irradiance is still visible, namely below 2600 ft (in Jerlov's type 1A-B water). Hopefully this will be possible in the near future. This cruise was very valuable to ground-truth completely new technology, demonstrating that the techniques will work, with some minor modifications. The Vision and Bioluminescence science team looks forward to conducting similar experiments at greater depths.

Appendix 1:
Submersible Dive Summary

Date	Dive ID	Latitude	Longitude	Max Depth (ft)	Dive Time	Total Bottom Time	Forward Observer	Aft Observer	# Video Tapes
19-Aug	JSL2-3314	32° 00.961N	077° 42.1312W	2152	03:22	02:30	Pomponi	Widder	2
19-Aug	JSL2-3315	32° 00.9896N	077° 42.1754W	2163	03:16	02:12	Widder	Frank	2
20-Aug	JSL2-3316	32° 00.9779N	077° 42.0911W	2153	03:29	02:31	Frank	Widder	1
20-Aug	JSL2-3317	32° 01.2586N	077° 39.6625W	2560	03:32	02:33	Reed	Joannin	2
21-Aug	JSL2-3318	32° 00.8834N	077° 42.2326W	2180	01:51	00:31	Herring	Roman	1
21-Aug	JSL2-3319	32° 00.9731N	077° 43.3354W	2160	02:04	01:03	Heine	Matz	1
21-Aug	JSL2-3320	32° 01.5077N	077° 40.8250W	2064	01:58	01:05	McMullin	Warrant	1
22-Aug	JSL2-3321	32° 01.6585N	077° 40.4577W	2347	03:29	02:24	Pomponi	Keener-Chavis	1
22-Aug	JSL2-3322	32° 01.6837N	077° 40.7777W	2126	03:24	02:27	Pomponi	Winder	1
23-Aug	JSL2-3323	32° 37.2812N	078° 19.7401W	690	03:25	03:00	Reed	Samples	3
23-Aug	JSL2-3324	32° 43.8012N	078° 06.7713W	655	03:13	02:49	Widder	Russell	2
24-Aug	JSL2-3325	32° 43.7656N	078° 06.8486W	674	02:31	01:56	Askew,Jr	Johnsen	1
24-Aug	JSL2-3326	32° 43.7606N	078° 06.8394W	654	03:24	03:02	Pomponi	Pitts	1
25-Aug	JSL2-3327	31° 40.4690N	079° 09.5532W	1730	03:20	02:28	Reed	Keener-Chavis	2
25-Aug	JSL2-3328	31° 43.9141N	079° 05.9891W	1730	03:21	02:34	Frank	Herring	2
26-Aug	JSL2-3329	31° 43.8741N	079° 06.1004W	1773	03:22	02:39	Johnsen	Heine	2
26-Aug	JSL2-3330	31° 43.4243N	079° 06.2902W	1804	03:15	02:25	Pomponi	Willoughby	1
27-Aug	JSL2-3331	31° 41.4238N	079° 08.5042W	1727	03:21	02:33	Reed	Cousin	2
27-Aug	JSL2-3332	31° 41.6681N	079° 08.3206W	1741	03:23	02:36	Herring	McMullin	2
29-Aug	JSL2-3333	30° 28.9358N	079° 39.5056W	1950	03:20	02:39	Pomponi	Arik	1
29-Aug	JSL2-3334	30° 29.5709N	079° 40.2917W	1910	03:50	02:58	Widder	Matz	2
30-Aug	JSL2-3335	28° 46.5255N	079° 37.5785W	2520	03:14	02:02	Frank	Warrant	2
30-Aug	JSL2-3336	28° 16.0452N	079° 36.4499W	2500	03:42	02:31	Askew,Jr	Reed	2

Appendix 2:
Samples Collected by Submersible for Pharmaceutical Discovery

Date	Dive ID	Dive Target	Depth Range (ft)	Sample Descriptions
8/19/2002	JSL2-3314	Stetson Lophelia Bank 1	2095-2152	Antipathes Sp.1, Ifalukellidae, New Sp.?, Ye Morph, Plakinidae, Oceanapia Sp., Enallopsammia profunda, Lophelia pertusa, Spongosorites Sp., Lyssacinosida, Geodia Sp, Lyssacinosida, Halichondriidae, Ifalukellidae, New Sp.?, Or Morph, Plumarella pourtalessi (Verrill, 1883), Sediment, Bathypsammia? Sp., Clavularia Sp., Eunephthya Nigra (Pourtales, 1868), Tamaria? Sp.
8/19/2002	JSL2-3315	Stetson Lophelia Bank 2 Wpt. 21	2083-2163	Ifalukellidae, New Sp.?, Or Morph, Lychniscosida?, Pachastrellidae, Phakellia Sp., Decaying Wood?
8/20/2002	JSL2-3316	Stetson Lophelia Bank 3	2151-2153	Phakellia Sp., Spongosorites Sp., Eunephthya nigra (Pourtales, 1868), Ifalukellidae, New Sp.?, Or Morph, Gorgonacea, Hydroida
8/20/2002	JSL2-3317	Stetson Lophelia Bank 4	2522-2060	Pachastrellidae, Pachastrellidae, Corallistidae, Geodia Sp., Keratoisis flexibilis (Pourtales, 1868), Wh Morph, Antipathes Sp.1, Pachastrellidae, Pachastrellidae, Leiodermatium Sp., Lyssacinosida, Pachastrellidae, Eunephthya nigra (Pourtales, 1868), Spongosorites Sp., Phakellia Sp., Sediment, Gorgonacea, Several Spp.
8/21/2002	JSL2-3318	Stetson Lophelia Bank 1	2002-2180	Antipathes Sp.1, Keratoisis flexibilis (Pourtales, 1868), Wh Morph, Phakellia Sp., Lyssacinosida, Biemnidae
8/21/2002	JSL2-3319	Stetson Lophelia Bank 1	2157-2160	N/A
8/21/2002	JSL2-3320	Stetson Lophelia Bank 1	2056-2064	Corallistes Sp., Leiodermatium? Sp., Lychniscosida?, Spongosorites Sp., Plakinidae, Pachastrellidae, Halichondriidae, Lyssacinosida, Lophelia pertusa, Hexasterophora, Phakellia Sp., Membranipora? Sp., Octocorallia, Several Spp., Solitary Scleraetinia, Enallopsammia profunda
8/22/2002	JSL2-3321	Stetson Lophelia Bank 5	2049-2347	Oceanapia Sp., Hexactinellida, Plakinidae, Lyssacinosida, Pachastrellidae, Petrosiidae, Siphonodictyon (Aka) Sp., Pachastrellidae, Ancorina? Sp., Pachastrellidae, Scleractinia, Several Spp.
8/22/2002	JSL2-3322	Stetson Lophelia Bank 5	2059-2126	Holothuroidea, Thesea Nr. parviflora (Deichmann, 1936), Acanthogorgia Nr. aspera (Pourtales, 1867), Geodia Sp., Plumarella pourtalessi (Verrill, 1883), Pachastrellidae, Halichondrida, New Sp.?, Pachastrellidae, Acanthogorgia aspera (Pourtales, 1867), Sediment, Coelopleurus floridanus + Stylocidaris? Sp., Parthenope Sp. + Hermit Crab, Ophiuroidea [Basket Star]
8/23/2002	JSL2-3323	Charleston Lumps South 4	630-690	N/A
8/23/2002	JSL2-3324	Charleston Lumps North	603-655	Poecilosclerida ?, Ircinia New Sp.?, Hydroida, Aciculites Sp., Spongosorites Sp., Hexasterophora, Spirophorida, Petrosiidae, Plumarella pourtalessi (Verrill, 1883), Decapoda (Crab)
8/24/2002	JSL2-3325	Charleston Lumps North	674	Spirophorida, Hagfish Slime
8/24/2002	JSL2-3326	Charleston Lumps North	603-654	Spirophorida, Aciculites Sp., Ircinia New Sp.?, Strongylophora Sp., Choristida, Auletta Sp., Thesea Nr. parviflora (Deichmann, 1936), Sediment
8/25/2002	JSL2-3327	Savannah Lithoherm	1665-1730	Choristida, Phakellia Sp.2, Pachastrellidae, Phakellia Sp.2, Pachastrellidae, Pachastrellidae, Ifalukellidae, New Sp.?, Ye Morph, Pachastrellidae, Hexasterophora, Axinellida, Biemnidae, Pachastrellidae (Different From Others On This Dive), Sediment, Geryon ? Sp. (Golden Crab), Stylaster Sp., Gorgonacea, Ircinia New Sp.?
8/25/2002	JSL2-3328	Savannah Lithoherm	1688-1730	Hexasterophora, Hexasterophora, Hexasterophora, Biemnidae, Enalopsammia protunda, Gorgonacea, Several Spp., Madrepora oculata, Asteroidea + Cidaroidea, Lophelia pertusa + Madrepora oculata
8/26/2002	JSL2-3329	Savannah Lithoherm	1707-1773	Keratoisis flexibilis (Pourtales, 1868), Wh Morph, Biemnidae, Ifalukellidae, New Sp.?, Ye Morph, Hexasterophora, Choristida, New Sp.?, Asteroidea, 2 Spp., Eunicella modesta (Verrill, 1883)
8/26/2002	JSL2-3330	Savannah Lithoherm	1703-1804	Raspailiidae, Phakellia Sp., Keratoisis flexibilis (Pourtales, 1868), Wh Morph, Heterotella Sp., Ifalukellidae, New Sp.?, Or Morph, Hexactinellida, Hexactinellida, Sediment, Lophelia Pertusa, Stylasteridae
8/27/2002	JSL2-3331	Savannah Lithoherm	1704-1727	Hexactinellida, Biemnidae, Hexactinellida, Ifalukellidae, New Sp.?, Or Morph, Hexactinellida, Pachastrellidae, Heterotella Sp., Sediment, Sediment, Madrepora oculata + Stylasteridae
8/27/2002	JSL2-3332	Savannah Lithoherm	1691-1741	Stylocordyla Sp., Phakellia Sp.3, Heterotella Sp., Plumarella pourtalessi (Verrill, 1883), Antipathes Sp.2, Antipathes Sp.1, Stylasteridae
8/29/2002	JSL2-3333	Jacksonville Lophelia Lithoherms	1852-1950	Keratoisis flexibilis (Pourtales, 1868), Wh Morph, Keratoisis flexibilis (Pourtales, 1868), Or Morph, Pachastrellidae?, Hexactinellida, Antipathes bipinnata, Spongosorites Sp., Petrosiidae, Actinaria, Placogorgia? Sp.1, Pachastrellidae, Sediment
8/29/2002	JSL2-3334	Jacksonville Lophelia Lithoherms	1898-1910	Keratoisis flexibilis (Pourtales, 1868), Wh Morph, Keratoisis flexibilis (Pourtales, 1868), Or Morph, Placogorgia? Sp.1, Chrysogorgia squamata (Verrill, 1883), Hexactinellida, Antipathes bipinnata, Sediment, Plexauridae Unid. Sp.1, Anthomastus grandiflorus Verrill, 1922, Actinaria, Hexactinellida, Solitary Scleractinia
8/30/2002	JSL2-3335	Cape Canaveral Lophelia Pinnacles	2435-2520	Actinaria
8/30/2002	JSL2-3336	Cocoa Beach Lophelia Pinnacles	2407-2500	Isidella Sp., Pterostenella? New. Sp?, Hexactinellida, Anthomastus grandiflorus Verrill, 1922, Sediment, Enallopsammia profunda, Zoanthidae

Appendix 3:
Samples Collected by Plankton Net for Bioluminescence Studies

Date	Gear Type	Time	Depth	Sample Description
08/19/02	Small Plankton Net	10:00	Surface	small medusa jelly, blue salps, miscellaneous copepods, Trichidesmium
08/20/02	Small Plankton Net	14:00	Surface	Pontellid copepods, Trichidesmium, miscellaneous copepods
08/20/02	Small Plankton Net	14:30	Mid-water	Boroe larvae, Dinoflagellates, Trichidesmium, arrow worms, larvaceans, miscellaneous copepods
08/23/02	Small Plankton Net	01:15	Surface	Trichidesmium, miscellaneous copepods, arrow worms, larvaceans
08/23/02	Small Plankton Net	01:45	Mid-water	Trichidesmium, miscellaneous copepods, Ceratium sp., Round Autotrophic Dinos, Chaetocerous, Rhizosolenia sp
08/24/02	Small Plankton Net	12:50	Mid-water	miscellaneous copepods, Trichidesmium, Ceratium furca?, Protoperidinium
08/24/02	Small Plankton Net	22:25	Surface	miscellaneous copepods, Trichidesmium
08/24/02	Small Plankton Net	23:15	Mid-water	miscellaneous copepods, Trichidesmium, Ceratium furca?, Protoperidinium depressum?, Round Autotrophic Dinos
08/26/02	Small Plankton Net	01:25	Mid-water	miscellaneous copepods, Trichidesmium, Protoperidinium, Round Autotrophic Dinos, larvaceans, Small siphonophore?

Appendix 4:
Lesson Plans Developed for Expedition

Grades 5-6

The Sea with No Shores

In this activity, students will be able to infer why the brown alga, *Sargassum*, is likely to be home to many marine organisms and infer that the populations of organisms in the *Sargassum* are dependent on each other for survival.

An Ocean of Weather

In this activity, students will learn that the ocean and atmosphere work together as a system, will experiment to find out that heat transfer from the ocean causes the Earth's weather, and will make and explain an ocean water cycle.

Grades 7-8

Bioluminescence and Deep-sea Life

In this activity, students will learn that white light (visible light) is comprised of all colors of the spectrum; that the quantity of light decreases with increasing depth in the ocean; that the quality of light changes with increasing depth; that red light penetrates water the least and that blue light penetrates water the most; and that many ocean organisms are bioluminescent. Students will also learn that bioluminescent light is usually blue; why organisms bioluminesce; and will learn about several bioluminescent animals through independent research.

Reef Fish Real Estate in the South Atlantic Bight

In this activity, students will research a species of reef fish to determine its habitat requirements as both a juvenile and an adult. Students will use this information to create a pamphlet in the style of a real estate brochure that will describe the habitat and food requirements of a particular reef fish species as adults and as juveniles and describe how the water quality of local watersheds and other stresses can affect that particular reef fish.

Grades 9-12

Mud Is Mud….Or is It?

In this activity, students will learn to compare and contrast similar sediment samples, use the computer as a learning tool, and identify different variables that affect deep-sea habitats and organisms.

Blinded By the Light!!

In this activity, students will recognize that the colors they see are a result of the reflection of light and that other colors of light are absorbed; predict what color an object will appear when light of different colors is shined upon it; predict what color(s) will be produced when different colors of light are mixed; and identify the three primary colors and three secondary colors of light.

Gilligan, the Skipper, and a 3-Hour Tour??

In this activity, students will be able to use dimensional analysis (factor-label) to convert units; read a scale on a map and determine distances from point to point; use knowledge of vectors to calculate resultant velocities; and use simple algebra and the velocity equation (V=distance/time) to solve for velocity, distance, and/or time.

In Gyre Straits

In this activity, students will use inquiry to infer the bathymetry of the ocean floor located below the ocean surface that causes the formation of an eddy in the Gulf Stream; test their ocean floor designs by building models that simulate the Gulf Stream's course over their ocean floor while observing if an eddy forms; predict what changes to their model may produce an eddy; and reconstruct a simple model of the actual ocean floor that results in the Charleston Gyre and compare it to their test models.

Drifting Downward
In this activity, students will describe the characteristics of plankton; develop abilities necessary to do scientific inquiry; test the effects of different salinity and temperature on the vertical movement of a model of a planktonic organism; and calculate the velocity of the plankton model.

Reproduction Lottery
In this activity, students will be able to explain that fishes that reproduce externally have to release great numbers of eggs and milt (sperm) in order to ensure fertilization.

Light at the Bottom of the Deep, Dark Ocean???
In this activity, students will participate in an inquiry activity; relate the structure of an appendage to its function; and describe how a deepwater organism responds to its environment without bright light.

Spawn!
In this activity, students will understand that the ability of certain reef fishes to have a successful spawning is dependent on numerous environmental conditions. They will also be able to list some of the factors needed by reef fishes in the South Atlantic Bight to have a successful spawn.

At the Edge of a Continent
In this activity, students will learn how to interpret a bathymetric map; will learn the main features of the continental margin; will plot and graph bathymetric data; and will think about and discuss the bathymetry of the edge of the continental shelf.

Appendix 5:
Daily Logs and Background Pieces Written for NOAA's oceanexplorer.noaa.gov Web Site

Date/Title	Subject	Author
8/18/02 Leg 3 Begins!	Ocean Exploration port day and transit to Site 1	Paula Keener-Chavis National Education Coordinator/Marine Biologist NOAA Office of Ocean Exploration
8/19/02 Where Coral Castles Climb and Soar	Site 1 characterization	Paula Keener-Chavis National Education Coordinator/Marine Biologist NOAA Office of Ocean Exploration
8/20/02 Hagfish, My Biggest Nightmare!	Site 1 characterization	Paula Keener-Chavis National Education Coordinator/Marine Biologist NOAA Office of Ocean Exploration
8/21/02 Got It!	Teacher-at-Sea perspective and site 1 updates	Arte Roman High school Marine Science teacher Olympia High School, Orlando, Florida
8/22/02 Stetson's Reef Revisited	Lophelia reefs at site 1	John Reed, Senior Scientist Division of Biomedical Research Harbor Branch Oceanographic Institution
8/23/02 Plan B	Eye-in-the-Sea operations	Edie Widder, Ph.D., Senior Scientist Bioluminescence Department Harbor Branch Oceanographic Institution
8/24/02 Charleston Bumps, Lumps, and Humps, Oh My!	Site 2 characterization	Paula Keener-Chavis National Education Coordinator/Marine Biologist NOAA Office of Ocean Exploration
8/25/02 Rocked by Mother Ocean	Reflections on a dive	Paula Keener-Chavis National Education Coordinator/Marine Biologist NOAA Office of Ocean Exploration
8/26/02 I'm Partial to Sponges	Sponges at site 1 and 2	Shirley Pomponi, Vice President & Director of Research, Harbor Branch Oceanographic Institution
8/27/02 Lithoherms Yield New Discoveries	Site 3 characterization	Paula Keener-Chavis National Education Coordinator/Marine Biologist NOAA Office of Ocean Exploration
8/28/02 A View from the Window	Reflections on deep sea exploration	Dr. Peter Herring Southampton Oceanographic Centre Southampton, U.K.
8/29/02 Deep Coral Reefs May be More Extensive Than Their Shallow Water Counterparts	Site 4 characterization	Paula Keener-Chavis National Education Coordinator/Marine Biologist NOAA Office of Ocean Exploration
8/30/02 "The Oceans Are Different"	General summary of findings and final day	Paula Keener-Chavis National Education Coordinator/Marine Biologist NOAA Office of Ocean Exploration
Background Piece: What's in a Name - Coral Reef?	Deep water coral reef – Oculina and Lophelia	John K. Reed, Senior Scientist Harbor Branch Oceanographic Institution, Division of Biomedical Marine Research
Background Piece: What is a Natural Product?	What natural products are, why they are useful, and how they are extracted	Amy E. Wright, Ph.D. Director, Division of Biomedical Marine Research Harbor Branch Oceanographic Institution
Background Piece: Biological Diversity Equals Chemical Diversity- The Search for Better Medicines	Human medicines from the ocean – how the chemical compounds are found and evaluated	Amy E. Wright, Ph.D. Director, Division of Biomedical Marine Research Harbor Branch Oceanographic Institution
Background Piece: Visual Ecology and Bioluminescence	How visual ecology and bioluminescence will be studied during the mission	Tamara Frank, Biological Oceanographer Harbor Branch Oceanographic Institution Edith A. Widder, Senior Scientist Harbor Branch Oceanographic Institution

Appendix 6:
Daily Logs Written for the Harbor Branch www.at-sea.org Web Site

Date	Subject	Author
08/17/02	mission goals; what they plan to do	Brian Cousin Video Production Specialist Harbor Branch Oceanographic Institution
08/19/02	1st dive of mission; multidisciplinary aspect; sample processing protocol	Brian Cousin Brian Cousin Video Production Specialist Harbor Branch Oceanographic Institution
08/20/02	recovery/attempted recovery of benthic traps and Eye-In-the-Sea; working in a current	Brian Cousin Video Production Specialist Harbor Branch Oceanographic Institution
08/21/02	dive site 1 description; first JSLII dive for the BMR researchers; looking for the Eye-In- the-Sea	Brian Cousin Video Production Specialist Harbor Branch Oceanographic Institution
08/22/02	tucker trawl; reflectance studies; computer visualization of Stetson's reef site	Brian Cousin Video Production Specialist Harbor Branch Oceanographic Institution
08/23/02	transit to Charleston Bump; benthic trap and Eye-In-the-Sea deployment	Brian Cousin Video Production Specialist Harbor Branch Oceanographic Institution
08/24/02	reflections on life at sea	Dr. Shirley Pomponi Co-Principal Investigator, Chief Scientist Vice President and Director of Research Harbor Branch Oceanographic Institution
08/25/02	transit to Savannah *Lophelia* bank; sponge prep. for taxonomic evaluation; Arte Roman, educator at sea	Brian Cousin Video Production Specialist Harbor Branch Oceanographic Institution
08/26/02	Gulf Stream; summer squalls; sub dives; tucker trawl; blue-water SCUBA dive	Brian Cousin Video Production Specialist Harbor Branch Oceanographic Institution
08/27/02	correspondent's account of a submersible dive	Brian Cousin Video Production Specialist Harbor Branch Oceanographic Institution
08/28/02	a veteran scientist's reflections on deep sea research	Dr. Peter Herring Professor Southampton Oceanography Centre
08/29/02	reduced operations on site 3; transit to site 4 on Florida-Hatteras slope; sub dive site 4	Brian Cousin Video Production Specialist Harbor Branch Oceanographic Institution
08/30/02	dive site 4a - off Canaveral, FL; summary of cruise	Brian Cousin Video Production Specialist Harbor Branch Oceanographic Institution

Appendix 7:
Mission 3 Science Team

Name	**Affiliation**	**Role**
Tammy Frank	HBOI	Chief Scientist (Vision and Bioluminescence)
Edith Widder	HBOI	Co-Chief Scientist (Vision and Bioluminescence)
Shirley Pomponi	HBOI	Chief Scientist (Pharmaceutical Discovery)
John Reed	HBOI	Co-Chief Scientist (Pharmaceutical Discovery)
Amy Wright	HBOI	Co-Chief Scientist (Pharmaceutical Discovery)
Craig Russell	NOAA/NOS	Mission Coord./Data Manager
Paula Keener-Chavis	NOAA/Ocean Exploration	Education Coord./*OE* Web Site Coord.
Brian Cousin	HBOI	Videographer/*At-Sea* Web Site Coord.
Erika Heine	Johns Hopkins University	Scientist (Vision and Bioluminescence)
Peter Herring	SOC - UK	Scientist (Vision and Bioluminescence)
Nicholas Joannin	HBOI	Scientist (Pharmaceutical Discovery)
Sonke Johnsen	Duke University	Scientist (Vision and Bioluminescence)
Mike Matz	Whitney Laboratory	Scientist (Vision and Bioluminescence)
Nicole McMullin	FAU	Scientist (Vision and Bioluminescence)
Tara Pitts	HBOI	Scientist (Pharmaceutical Discovery)
Arte Roman	Olympia High School, FL	Educator-at-Sea
Gail Samples	HBOI	Scientist (Pharmaceutical Discovery)
Laverne Taylor	UM Marine Technology Group	Survey Technician
Eric Warrant	University of Sweden	Scientist (Vision and Bioluminescence)
Robin Willoughby	HBOI	Scientist (Pharmaceutical Discovery)
Priscella Winder	HBOI	Scientist (Pharmaceutical Discovery)